Reconfiguration of Webb-style Gliders for Routine Turbulence Measurements

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LONG-TERM GOALS

The long-term goal of this program is to understand the physics of small-scale oceanic processes including internal waves, hydraulics, turbulence and microstructure that act to perturb and control the circulation in coastal oceans and, in doing so, affect the propagation of sound and light. Ongoing studies within the **Ocean Mixing Group** at OSU emphasize observations, interaction with turbulence modelers and an aggressive program of sensor / instrumentation development and integration. This includes extending measurements to new platforms such as gliders so that we can make continued measurements *where* ships cannot go (or *when* they cannot be there, such as during periods of extreme surface forcing).

OBJECTIVES

Gliders offer a means of making two very valuable types of relatively autonomous measurements in the ocean. The first is the type of repeated routine observation that permits establishment of a climatology from which significant deviations can be identified and addressed. The second is the observation of extreme events (such as hurricanes) that cannot be made from ships. Over the past 20 years, we have established standards of ocean turbulence measurements and have extended our ship-based vertical and horizontal profiling packages to moored mixing measurements. It has been a natural evolution to use this expertise to integrate new sensors into gliders that will both begin to define climatologies of mixing in coastal waters and lead to turbulence measurements in events such as hurricanes for which we have limited or no observation.

In particular, the mechanical design of the Webb Research glider is robust and proven. The prospects for measuring turbulence and surface waves on these gliders have been recently tested by us by strapping a turbulence / motion-sensing package to both OSU and Rutgers gliders. Results have been sufficiently encouraging that we are now reconfiguring two existing gliders (one at Oregon State University, the other at Rutgers University) to achieve the following objectives from an integrated package:

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14. ABSTRACT
The long-term goal of this program is to understand the physics of small-scale oceanic processes including internal waves, hydraulics, turbulence and microstructure that act to perturb and control the circulation in coastal oceans and, in doing so, affect the propagation of sound and light. Ongoing studies within the Ocean Mixing Group at OSU emphasize observations, interaction with turbulence modelers and an aggressive program of sensor / instrumentation development and integration. This includes extending measurements to new platforms such as gliders so that we can make continued measurements where ships cannot go (or when they cannot be there, such as during periods of extreme surface forcing).

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- routine and continuous measurement of turbulence in the form of the temperature variance dissipation rate, χ, the turbulence kinetic energy dissipation rate, ε, and the turbulence diffusion coefficients, K_T and K_ρ;
- routine and continuous measurement of water-column velocity;
- routine measurement and transmission of significant wave height and direction when surfaced using a 6-axis accelerometer package;
- detection of nonlinear internal waves using the same motion package and transmission of wave properties.

APPROACH

We have added external turbulence pods to gliders. These pods include inertial motion (6 components of acceleration), fast thermistors, shear probes and gust probes (to measure three components of velocity with multiple pitot tubes). The advantage of an external pod is that it can be deployed on any glider of the same design. However, a significant disadvantage is that it slows the glider speed, thereby reducing its range for a given deployment. Analyses of the data obtained to date have been used to incorporated the pod into an integrated turbulence package (Figure 1).

WORK COMPLETED

Tests were conducted in June 2008 (external pod) and June 2009 (internal pod) over Stonewall Bank on Oregon's continental shelf. These were coordinated with Chameleon turbulence profiling. A glider launched with an external turbulence package and internal inertial motion package was launched by the Rutgers glider group off NJ in early September 2008 to encounter Tropical Storm Hanna, which it did. This glider was recovered in early October following a successful mission through an energetic storm (Figures 2-4).

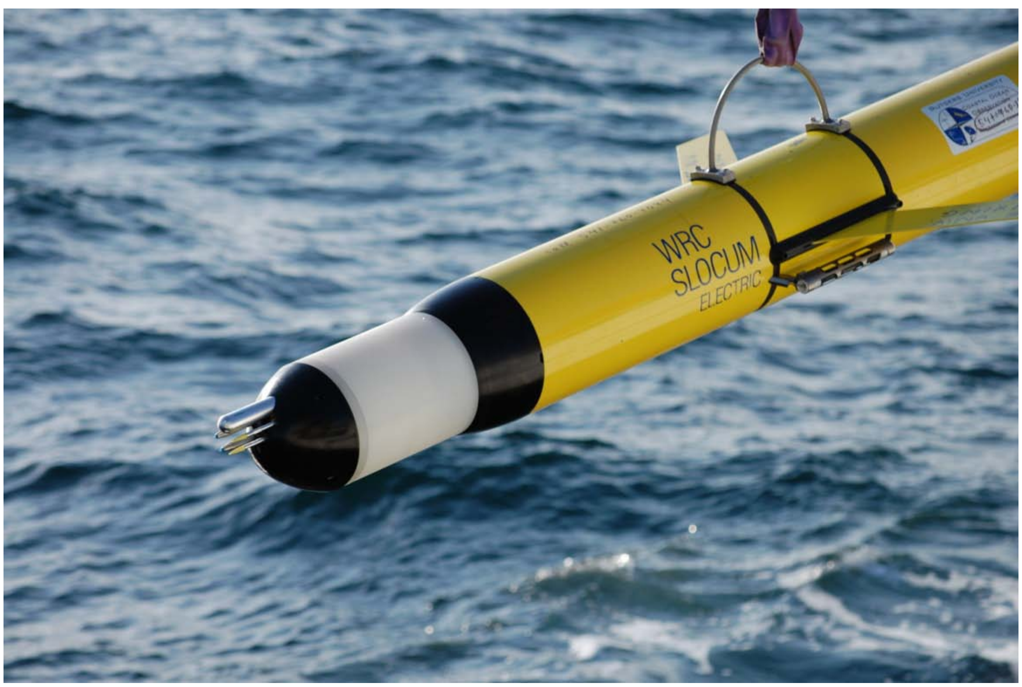

Figure 1 – Photograph of Webb glider with internal turbulence pod upon deployment in June 2009 over Stonewall Bank on Oregon's continental shelf.

RESULTS

Tropical Storm Hanna cooled the sea surface over the Mid-Atlantic Bight by several degrees (Figure 2). Where did the heat go?

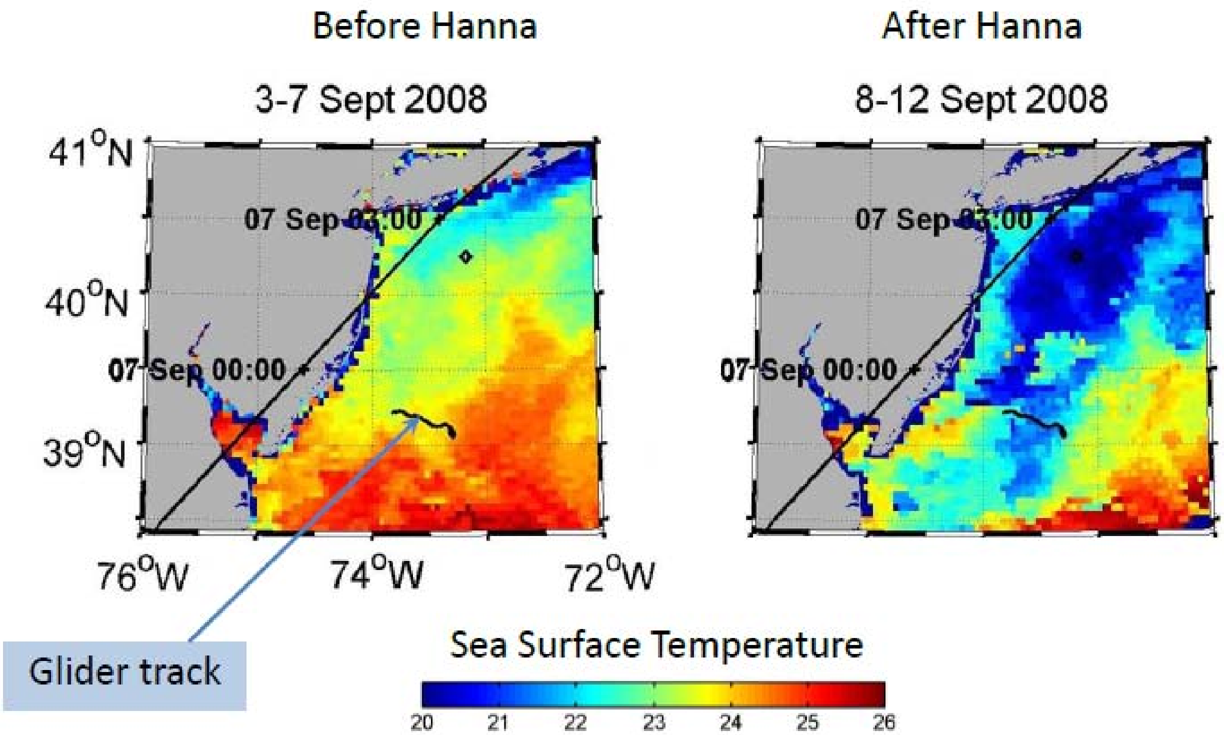

Figure 2 – Sea surface temperature over the Mid-Atlantic Bight prior to and following the passage of Tropical Storm Hanna in August 2008.

Glider sections of temperature, Cox number and turbulence heat flux derived from fast thermistor measurements are shown in Figure 3. In rough terms, there existed a relatively well-mixed surface layer separated by a strong pycnocline at mid-water depth from a relatively well-mixed bottom layer. The effect of the storm is witnessed throughout the water column.

The integrative effect of the storm is characterized by the changing mixed layer temperature (Figure 4). The cooling rate of the mixed layer, dT/dt, is compared to the cooling due to vertical mixing of heat through the pycnocline to the bottom layer, dJ_q/dz. The approximate balance $dT/dt \approx dJ_q/dz$ indicates that the cooling mixed layer is completely accounted for by heating of the bottom layer. We have not yet had the opportunity to evaluate surface heat fluxes (using bulk formulae), but, based on previous observations, expect these to be of the same magnitude.

From these measurements, we conclude that a significant cooling of the mixed layer comes from through the pycnocline.

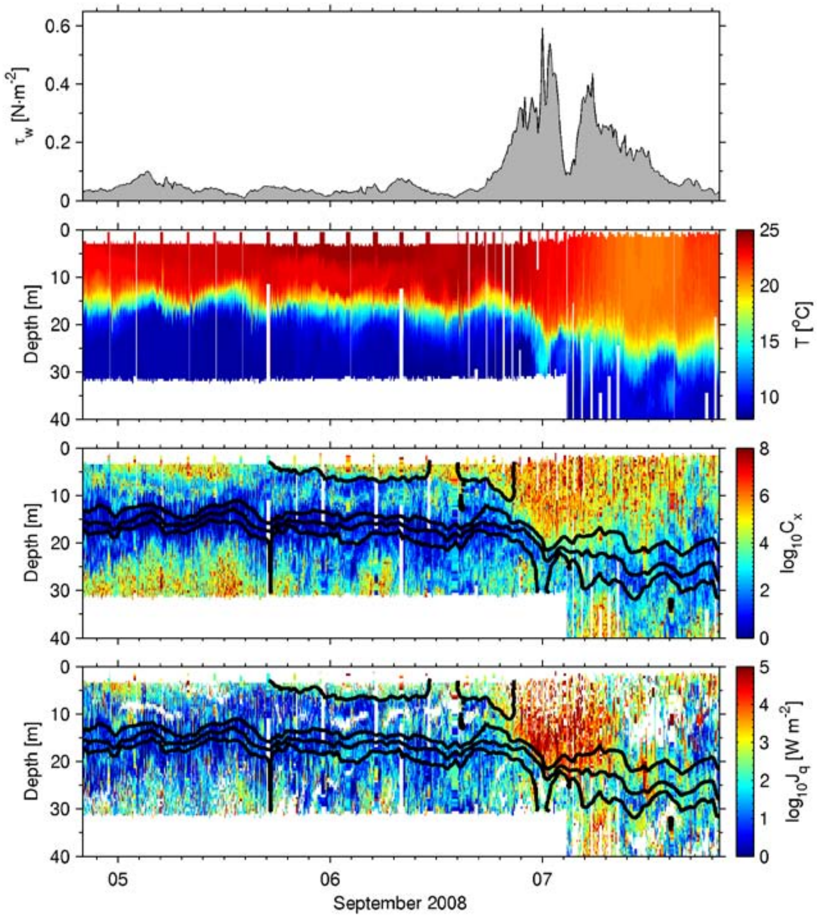

Figure 3 –– Upper panel – time series of wind stress over Mid-Atlantic Bight - Tropical Storm Hanna passed on August 6-7. Glider series of temperature (2nd panel), Cox number (3rd panel) and turbulence heat flux (4th panel) along the path shown in Figure 2.

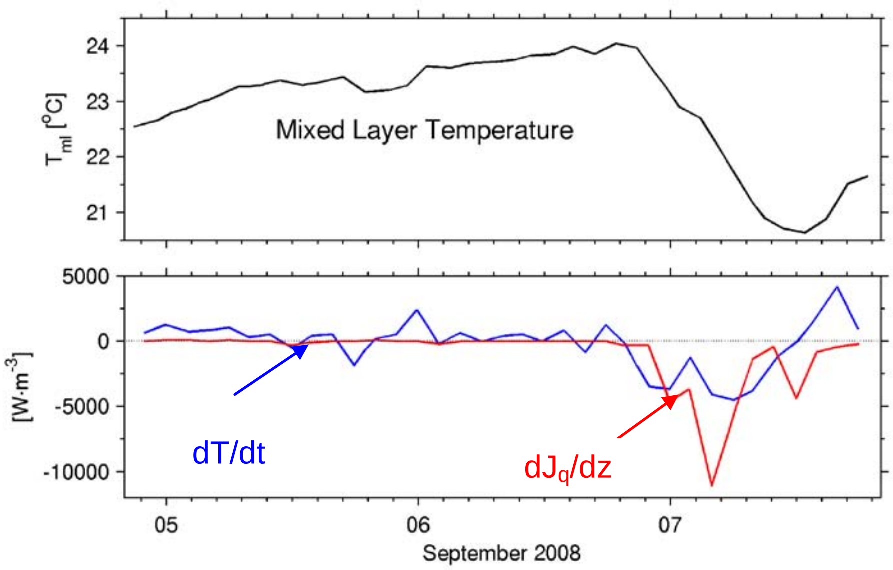

Figure 4 –– Upper panel - mixed layer temperature along the glider path. Lower panel – time rate of change of the temperature in the mixed layer (blue); vertical divergence of the turbulence heat flux in the pycnocline.

During 2008, Philip Wiles (NERC Fellow) visited Oregon State University to work with us on glider observations. He has done much of the analysis leading to the result related above, which was reported on at the Gordon Conference on Coastal Ocean Circulation in June 2009. A draft manuscript is in progress (Wiles etal., 2009)

PUBLICATIONS

Wiles, P.J., J.N. Moum, S. Glenn, K. Shearman and J.D. Nash, 2009. Glider observations of pycnocline mixing over the Mid-Atlantic Bight induced by Tropical Storm Hanna, in draft form for *Geophys. Res. Lett.*